national accelerator laboratory

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MAIN ACCELERATOR CAVITY FREQUENCY-SELECTIVE DAMPING VIA SKIN EFFECT

DISCUSSION

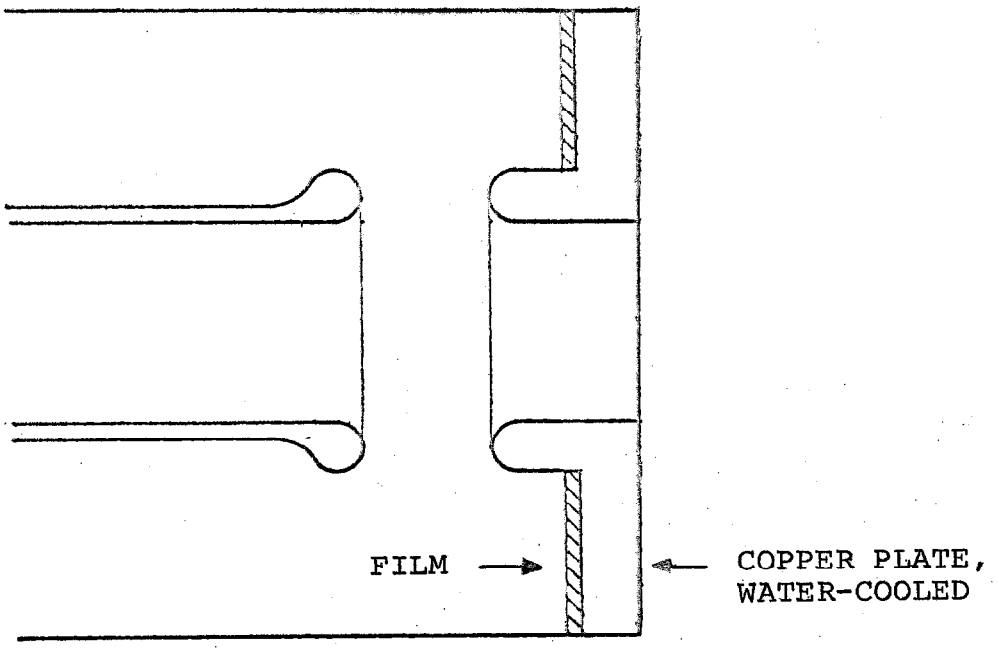
Ferrite damping of the M.A. cavities with gap-splitter ferrite has exhibited problems of ferrite overheating with accompanying breakage. It is evident that these are non-fundamental, hardware-type problems that can be solved, but it also appears that the time needed to solve them may be extensive.

The question arises - why not do all the damping with loaded irises or other coupled absorbers placed at the out-board ends of the cavity or along the sides? The introduction of damping in some form at the gap-splitter plate is for the purpose of damping some modes that could be excited by the beam but do not propagate around the bend and through the insulators. These modes would not couple to loaded irises in the air section of the cavity sides or end walls, and could lead, at some frequencies, to a high value of gap impedance which in turn would interact strongly with and cause beam loss for an intense beam. Damping at the gap-splitter could be changed to skin-effect damping via a thin layer (less than 1 skin-depth at 53 Mhz) of lossy material deposited over the water-cooled copper gap-splitter plate, with or without some inductive backing.

METALLIDING

Metalliding, discussed in the attached report,* could be used to introduce a layer of Silicon 5 to 10 mils thick on copper. General Electric has produced silicided copper, described in the report. The resistivity of Si is about $(220)^2$ times that of copper, and therefore siliciding is attractive as a means of providing a skin-loss layer over copper.

* Cook, Newell C. "Metalliding." Scientific American vol. 221 No. 2 (August, 1969), pp.38-46.



REQUIREMENTS OF THE LOSSY SKIN

The "skin" should meet certain requirements. It could be ferromagnetic, or be a material applied by metalliding.

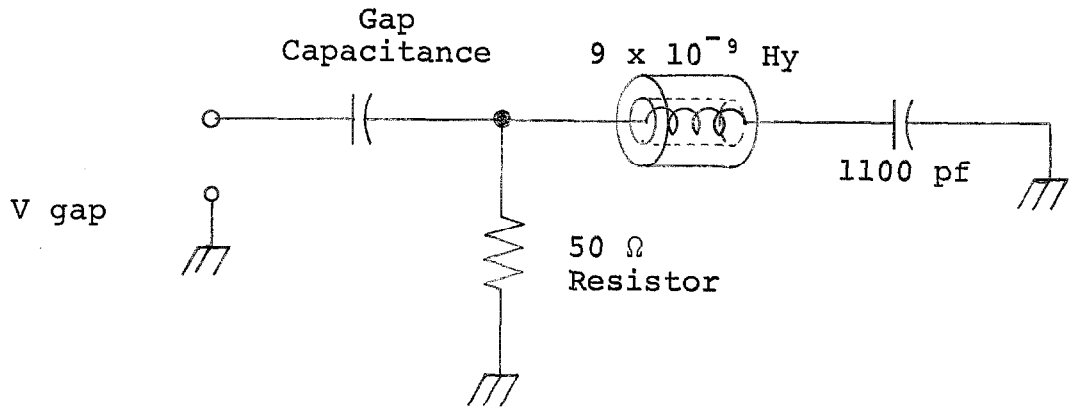
1. The layer must be thin (at 53 Mhz) compared to a skin depth. Thus, at 53 Mhz, most of the R.F. current will flow in the copper beneath. The R/square of the layer plus-copper backing will increase with frequency more rapidly than for copper alone. Eventually, for very high frequency, the surface resistivity will approach that of the film layer, since at high enough frequency, nearly all the current will flow in the film.
2. The film-on-copper combination can afford some loss at 53 Mhz, e.g. a power dissipation limit of say 2 KW per side of the gap-splitter. Therefore, the series R (equivalent resistors electrically in series with the gap displacement current) can be estimated: let I^2R = 2KW, I = 100 $Amps_{RMS}$, $R \simeq .2\Omega$
3. Since the resistance R is about that of eight squares in parallel, the resistance/square at 53 Mhz can be

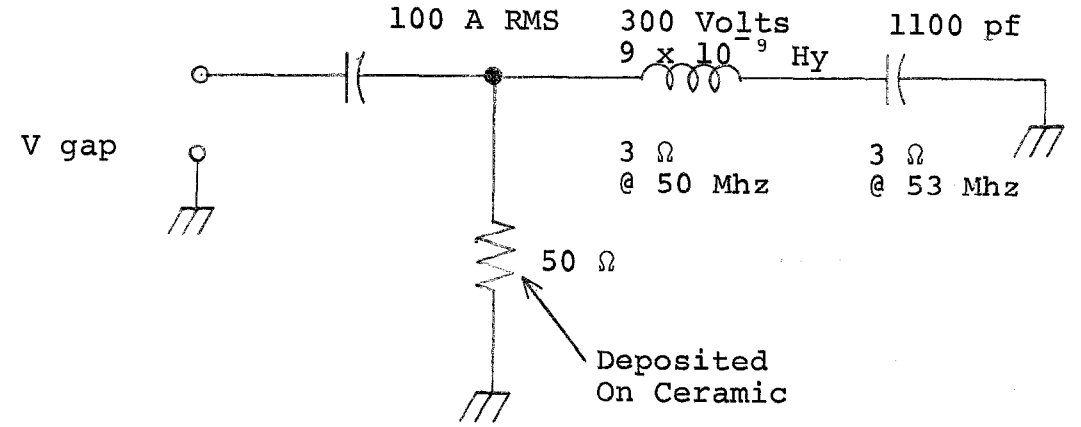
about 1.6 ohms/square. It follows that the material should be selected so the resistance/square of the film material is greater than 1.6 ohms/square. If the bulk resistance/square of the material can be made to approach $\sqrt{\frac{\mu\ \mu o}{\varepsilon\ \varepsilon o}}$ = 377 ohms/square, it becomes an excellent absorber at elevated frequency.

NOTE: The resistance/square of 31 mil Hipernom at 94 Mhz was measured to be .98Ω (.7Ω for other competing ferromagnetic materials).

INDUCTIVE BACKING (4.5 cm. of 60Ω line)

If we provide space for magnetic field between a lossy skin layer and the basic copper layer, we introduce an additional parameter. If, moreover, a series capacitor is introduced, skin loss can approach zero at the 53 Mhz fundamental frequency. An equivalent circuit follows.





The central purpose of the above described inductive backing, which could be achieved by a 4.5cm length of 60Ω vacuum coax line and cancelled in impedance by a capacitor, is to lower the skin loss at the fundamental and (relatively) increase loss at the higher frequencies.

SPLITTER PLATE WELD FINGER

Added welding lip length would be helpful at the weld joints on the splitter intermediate pipe to the splitter plate, in order that they may be made and broken several times.

Ref: See 0434.05 TM-224.

ATTACHMENTS: METALLIDING, by Newell C. Cook